DUTCH ELM DISEASE

MANAGEMENT GUIDE

BULLETIN ONE

DUTCH ELM DISEASE MANAGEMENT GUIDE

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PREFACE

In 1977, the U.S. Congress passed a bill that became Public Law 95-741, allowing federal funds to be used for a Dutch elm disease management program. That program, formally entitled the Technical Assistance and Public Information Outreach Program for Dutch Elm Disease Control and Elm Tree Utilization, began in 1978 and ended in 1981. Five states — Wisconsin, Minnesota, Georgia, Colorado, and California — participated in this National Dutch Elm Disease Demonstration Program (27). The program sought to demonstrate effective Dutch elm disease management and elm wood utilization procedures and to make this information available to interested individuals.

This Dutch Elm Disease Management Guide is the final phase of the demonstration program. Its purpose is to help states and municipalities develop and sustain successful Dutch elm disease management programs. The numbers in parentheses throughout the guide refer to selected references in the ''Literature Cited'' section. These references provide additional information on the subjects discussed in this publication.

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INTRODUCTION

Dutch elm disease has been present in the United States for more than half a century. Millions of elms that provide shade, windbreaks, and aesthetic pleasure are killed annually by this disease. People begin to understand the value of elm trees when — seemingly overnight — whole blocks of trees in their community become diseased and must be removed. They notice that houses become hot during the summer without the shade of large elms in the yard. The wind also blows harder and the snow piles up higher against the house in winter without the buffer of elm trees. People notice, too, how bleak and ugly the landscape looks without the softening influence of living elms. As trees continue to succumb to Dutch elm disease and the effects of their removal are noticed, people question why their community did not prevent this widespread loss.

Communities have made individual attempts to deal with the disease, but these have often been costly and ineffective. This lack of success, however, does not reduce the need for adequate disease management programs. Because most communities contain virtually a small forest — often with many elms — disease management programs are important. The recommendations suggested in this guide can help communities reduce tree losses due to Dutch elm disease and keep the loss rate economically manageable. If Dutch elm disease is suppressed long enough, a city will be able to make the transition from an urban forest that is predominantly elm to one of mixed shade tree species.

Several factors must be considered before a community determines how intensive its Dutch elm disease program should be. The level of disease management chosen depends partly on:

1. How greatly the community values its existing elms;
2. What percentage of the total tree population is elm;
3. How many elms are on public and how many on private property; and,
4. How many elms are in highly visible and/or aesthetically important places such as parks or boulevards?

The following pages will inform the reader of the need for a Dutch elm disease management program. The various practices used in disease management are explained, making it easier for readers to decide which ones are fundamental to a community's program. Readers will also learn how to assign priority to nonessential practices, which, when used in addition to the practices deemed more essential, might further reduce tree losses and/or improve program cost-effectiveness. Readers with additional questions on the organization or operation of a disease management program should refer to the "Literature Cited" section for further information.

ADMINISTRATIVE REQUIREMENTS FOR DUTCH ELM DISEASE MANAGEMENT PROGRAMS

When a community establishes a Dutch elm disease management program, it must consider administrative as well as biological problems. Too often, not enough emphasis is placed on developing a public outreach and information program, a record-keeping system, or a disease ordinance. Some program managers also overlook the value of keeping municipal officials — who are responsible for providing city funds — advised on the progress of the disease.

Any Dutch elm disease management program can be effective when sufficient dollars, personnel, and equipment are available and handled efficiently. A community can develop a workable program if most or all of the following administrative steps (not listed in priority) are taken.

1. One permanent employee should be in charge of the forestry program. Dollars can be saved because no time is lost acquainting a new manager to the program each year.
2. A municipality should have a Dutch elm disease ordinance to enable its program to run smoothly. This ordinance should set time limits for removing diseased trees on private as well as public property, define how payment of tree removal on private property is handled (is it the responsibility of the homeowner, the city, or both), restrict stockpiling of non-debarked elm logs, and permit employees to enter private property to carry out management practices. An ordinance helps city residents recognize that Dutch elm disease is a public concern rather than a private problem.
3. The program manager should have complete control of his/her budget. Since Dutch elm disease management is a race against time, being able to spend the money whenever necessary enables the program to run smoothly and efficiently. Work should not stop because spending authority has not been received from the city council or the city administrator.
4. A good record-keeping system should be kept current so the manager can tell how program time and dollars are being spent. Accurate records are important in justifying financial requests or supporting decisions to concentrate personnel and equipment on certain aspects of disease management.
5. The program manager should have access to one or more work crews. This is especially necessary when city crews are responsible for removing trees. Since removal is regulated by a strict biological timetable, peak efficiency can be reached only if personnel and equipment are readily available. Work crews are also necessary for other jobs such as disrupting grafted roots and injecting systemic fungicides.
6. The municipal governing body must be advised on the fundamentals of disease management. An informed city government is more apt to recognize the need for financial assistance and be open to suggestions for ordinances concerning the Dutch elm disease management program.
7. Intensive public outreach and information programs should be developed. A knowledgeable public can encourage municipal officials to provide city funds for disease management programs. Using material obtained from county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations, the program manager can familiarize community residents with Dutch elm disease and its effects through public information meetings, training workshops, etc.

The following management practices are discussed in detail in this publication and are fundamental to a Dutch elm disease program.

- *Inventorying/mapping*
- *Surveying/disease detection*
- *Tree removal*
- *Disposal/utilization*

If one or more of these practices is reduced or eliminated, the overall program will significantly decrease in effectiveness. While inventorying a municipality's entire tree population is necessary, this procedure is usually done only at the beginning of the program. In subsequent years, information on trees planted and removed can be added to keep the inventory current. The other essential management practices — disease detection, tree removal, and disposal — are first performed along with the tree inventory at the start of the program; they are later repeated annually. Utilization of elm material can also be an important component of disease management because it enables a municipality to recover a part of its program investment.

Additional management practices are also discussed in detail on the following pages. Priorities assigned to these additional management practices vary according to the individual needs of a municipality.

INVENTORYING/MAPPING

Dutch elm disease management begins with inventorying and mapping the municipality's shade tree population on both public and private property. This helps determine where available dollars, personnel, and equipment will do the most good.

An inventory can be simple or complex. Some municipal officials choose just to count the elm trees. Others, interested in developing a tree maintenance and replanting plan, count all trees, evaluate their condition, determine what work will be done to each tree (whether it will be pruned, removed because it is under stress and susceptible to infection, etc.), and where new trees will be planted to replace those removed due to Dutch elm disease. Once the desired information is gathered on each tree, it can be stored for easy accessibility (17). Inventorying of the tree population is performed concurrently with disease detection, tree removal, and disposal.

Tree positions can be recorded on city maps so that individual elms can be located. In addition, each elm can be marked with a numbered aluminum or plastic tag that identifies the tree and the treatment it is to receive (4). Although these tags are durable, people do sometimes remove them. Tagging a large number of trees can be a monumental task. The program manager must decide if it is worth the time it takes an individual in the field to tag each tree.

Boundaries should be set around those parts of the city where Dutch elm disease management will be undertaken. The areas that contain a small number of elm and/or are inaccessible to work crews and equipment should be given a lower priority or excluded entirely from the program. For example, the City of Granite Falls, Minnesota, lies in a river valley surrounded by bluffs heavily covered with wild elm. An effective program was maintained by assigning priority to areas within the city's disease management zone. The inner city, where the elms were considered to be the most aesthetically and economically valuable, was assigned the highest priority. A buffer area was set up around this inner core; diseased trees in the buffer zone were promptly removed before the infestation could spread inward. A third area, the remainder of the residential section within the city limits, was lowest in priority. Limited tree removal was undertaken there.

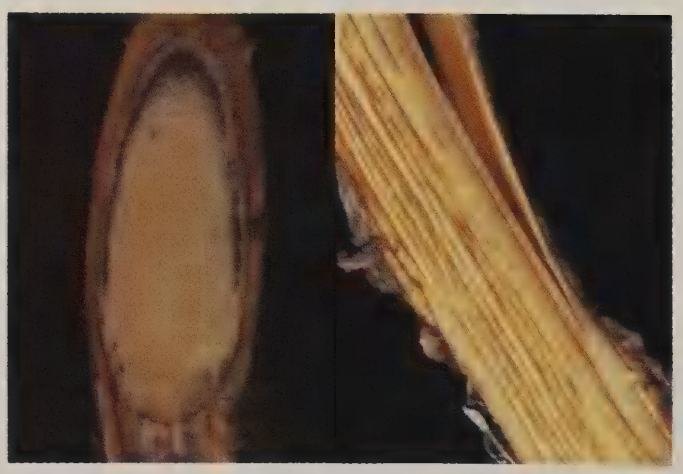
SURVEYING/DISEASE DETECTION

After the municipality's Dutch elm disease management area is determined, surveys must be organized to find all infected trees and beetle broodwood material. The most effective surveys are performed on foot as it is easier to enter backyards to locate diseased trees or piles of non-debarked elm logs not visible from the road.

The best programs include at least three annual surveys of the entire disease management area. The first survey should begin in the spring when leaf emergence is two-thirds completed and should take no longer than four weeks. All non-debarked or non-treated elm firewood, diseased trees, standing dead trees, felled trees, stumps, and limbs should be detected. During the first survey, program personnel should pay particular attention to finding "carry over" diseased trees (trees infected the previous autumn but not exhibiting obvious symptoms until the following spring when they leaf-out). The second and third surveys should be conducted four and eight weeks, respectively, after the first survey is completed. All newly infected trees should be detected as well as standing dead trees, felled trees, stumps, and limbs missed earlier in the season. A Dutch elm disease management program can include more than just three surveys. If a survey is completed before the four-week interval has passed, inspection should not be stopped. A new survey should begin immediately. In this way, surveys run back to back, resulting in continuous inspection during the growing season.

Detecting procedures vary according to the rate of elm loss. Program managers in cities with heavy elm losses often encourage field diagnosis of infected trees to reduce the time between disease detection and tree removal. Thus the individual observing the tree determines on the spot if the elm is infected. If the tree is infected, it is condemned and marked for removal. Field diagnosis of infection is based on the visual symptoms of wilting or flagging in one or more of the upper branches and of brown staining beneath the bark of sampled branches. Laboratory analysis is necessary when a definite diagnosis of the presence of Dutch elm disease is desired (1). Municipalities with low loss levels or few elms often feel they have the time to obtain laboratory analyses of all suspect trees. A sample sent to a laboratory for disease confirmation should be 1/2 to 3/4 inch in diameter and 4 to 10 inches long (4,9). The sample should contain discolored (stained) wood and must be from a branch that is wilting. The casual fungus, *Ceratocystis ulmi* (Buisman) C. Moreau, is difficult to isolate from dead, dried branches. County extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations can help communities learn to recognize disease symptoms for early field detection, send samples to be tested for disease, and set up laboratories to culture samples for the presence of the disease fungus.

Chlorosis, wilting, and browning of elm foliage are the initial symptoms of Dutch elm disease.



An elm limb cross section shows internal browning.

Stain can be observed when bark is removed from the sample.

Culturing of *Ceratocystis ulmi* from samples will confirm the diagnosis.

Ceratocystis ulmi has distinct fruiting structures that should be observed to confirm Dutch elm disease incidence.

The following steps should be taken to insure effective Dutch elm disease inspection surveys:

1. Disease surveys are as effective as the people conducting them. Individuals hired should be familiar with or capable of readily learning the symptoms of Dutch elm disease and the biology of both the causal fungus and the disease-transmitting elm bark beetles. Surveyors must also be able to distinguish Dutch elm disease from other common elm diseases and insect problems (10,24). A training program should be required for inexperienced personnel; even veteran tree inspectors might benefit from a refresher course.
2. A municipality should conduct at least three disease detection surveys of all elm species during the growing season.
3. Inspections should be made on foot. A car should be used only to approach an area and carry equipment.
4. Trees should be inspected from at least two different angles and, if possible, at different times of the day. Distance and lighting can influence the appearance of disease symptoms. Binoculars help inspectors identify the presence of disease in a tree's upper crown. Tree inspectors should have a pole pruner (up to 35-40 feet of extensions can be used), a small pair of pruning shears, a hatchet, and a pocket knife available to help remove suspect branches and check them for staining.

Adequate samples can be collected with the proper equipment.

5. When a tree inspector has doubts about condemning what appears to be an infected tree, a sample of the portion of the crown showing symptoms should be sent to a laboratory for culturing. In some municipalities (for example, a large city with a high level of disease incidence), valuable time can be lost if every obvious case of Dutch elm disease is analyzed in the laboratory for presence of the causal fungus. Some municipalities with low loss levels or with a small number of elm, however, do feel they have enough time to laboratory confirm all suspect trees.
6. Tree inspectors should continually search for woodpiles containing non-debarked elm wood as this wood provides a breeding habitat for elm bark beetles.

7. Tree inspectors should be aware that landowners often have questions about the disease management practices performed on their property. The tree inspector should be well-informed, courteous, and have a constructive attitude.

The size of the community's disease management area and the number of elms within that area determine the cost of an inspection survey and the number of tree inspectors needed to complete one. For assistance in planning a survey, the program manager can contact the local county extension agent, college or state university, and state or federal forestry/agricultural organization.

TREE REMOVAL

Identifying diseased trees is of little value unless those trees are promptly removed. The objective of prompt removal is to get rid of diseased trees — as well as firewood piles, felled trees, standing dead trees, stumps, and limbs — before bark beetle emergence. In most instances, during the active growing season, prompt removal of hazardous elm material occurs within 20 days of detection.

Most communities do not start management programs until they have a considerable number of diseased trees to remove. Although this is discouraging, an effective program can be developed by establishing a priority system of tree removal. This priority system should be based on local conditions such as insect development and location and spacing of elm trees. The training given by county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations can help communities identify these local conditions. Most municipalities starting new programs must use this priority system one to two years before catching up. Once the backlog is handled, the priority system is not needed and all infected, dying, and dead elm trees should be removed upon detection.

Although the program manager is responsible for identifying which trees to remove and in what order, the actual tree removal is usually handled in one of three ways: using a private contractor for all tree removal; using city crews for all tree removal; and using private firms to remove trees on residential property and city crews to remove trees on public property. Each of these three methods has advantages and disadvantages, as listed below.

- ***All tree removal done by a private contractor.***
  Private contracting is the most inexpensive way to remove a large number of trees as bidding competition keeps prices down. Contractors have the necessary equipment and experience to remove trees in areas with difficult access. The city can require the contractor to sign and adhere to a written set of tree removal specifications. Some municipalities give financial incentives for prompt tree removal. Also, the city can insist that the contractor meet specific requirements such as carrying accident insurance.

  The smaller city with few trees to remove might find this method too expensive. Extra supervision, which can increase labor costs, might be needed to ensure the contractor's compliance with the city's written specifications. This method requires a formal bidding process that can be time-consuming. Someone is also needed who can develop a contract that includes a strict and inclusive set of tree removal specifications. The city must be aware, too, that if for some reason the contractor cannot complete the assigned work, another firm will have to be hired or the city will have to finish removing the trees itself.

- ***All tree removal done by municipal street crews.***
  Municipal street crews can provide inexpensive tree removal when cities have the necessary equipment and few trees to remove. Bidding by private contractors is not competitive enough on small jobs to keep removal costs down. Since no contracts have to be written, the time-consuming bid-

ding process can be avoided. Experienced city crews need less supervision than a private contractor and they are available on short notice when fast tree removal is required.

Some city crews might lack the experience and equipment necessary to safely remove all trees. Also, if crews have other duties to perform, scheduling conflicts might delay tree removal.

- ***Tree removal done by a commercial firm on private property and by municipal street crews on public property.*** Using this method, the community avoids any liability resulting from city crews working on private property. Also, if tree losses on public property exceed predictions, the private contractor is available to help.

  Removal costs might be higher since the private contractor will probably be removing most of the difficult-to-reach rather than the most easily removed trees. Also, this method involves more administrative work because two crews must be supervised and assigned duties.

A professional arborist should be contacted for tree removal in urban locations.

Once a community has decided on a removal method and has identified diseased trees, it must still deal with city residents who cannot afford to remove infected trees on their property. Best results in prompt removal are obtained when the city assumes the entire cost on both public and private property. Free removal meets with little public resistance. If the city cannot pay the entire cost of tree removal, it should consider a subsidy program, with the private homeowner paying a percentage of the bill. Under some subsidy plans, the private homeowner, rather than the city, engages the contractor for removal. However, if subsidies are used, city personnel must spend additional time billing the homeowner for his or her part of the cost. Also, private homeowners not willing to pay any portion of the removal cost can be a problem. If a subsidy program is offered, the following requirements should be made:

1. Tree contractors used by private homeowners should be certified to comply with city rules and regulations.
2. The city should provide homeowners with a list of the city-certified tree contractors.
3. The city should have a contractor available to remove those trees on private property when the owners do not comply with the removal request.
4. No financial assistance should be given to homeowners who do not comply with the removal request and whose trees must be removed by the city.

In Wisconsin communities, efforts to speed up tree removal on private property led to the introduction of various incentive programs. These efforts varied from full or partial subsidies to adding removal costs to property taxes so payments could be spread over a number of years. In one cost-sharing program, the city and the resident shared 25 to 75 percent, respectively, of removal costs on private property. In another, the city assumed 23 percent of the cost incurred by residents who had their diseased elms removed within 20 days. Other cities reimbursed private individuals who had diseased elms removed within a specified number of days, paying them a designated amount per inch of tree diameter.

Once it has been determined who is to remove the diseased trees and how the removal cost will be handled, a decision must be made on what to do with the trees that are removed. Although in the past most elm material was burned or buried, other methods of utilization have now been developed. These alternatives are presented in the disposal/utilization portion of this guide.

DISPOSAL / UTILIZATION

The disposal of elm wood is the last of the fundamental disease management practices and is often the most difficult for a municipality to undertake. While burning and burying might be the easiest and most inexpensive ways for a municipality to dispose of hazardous wood, these accepted disposal methods do have limitations. Municipalities might find it difficult to obtain burning permits due to strict air pollution standards. Also, many landfills will no longer accept large tree trunks because of space limitations. These disposal methods eliminate the possibility of the municipality receiving anything for the trees it removes. Through utilization, however, it is possible for municipalities to recover part of their program investment.

Instead of burning or burying hazardous elm, some municipalities chip it, using their own equipment or that of a private contractor. Wood chips can be used for such things as mulch, animal bedding, and nature trails. Many disease management programs debark elm to produce non-hazardous firewood. This has become an important utilization method for states needing additional, less expensive ways of providing heat during the winter months. A few municipalities sell elm logs to sawmills. However, this is usually not profitable as the market price of elm lumber generally does not cover the cost of the tree removal. Also, urban elms do not produce quality sawlogs. They normally have short trunks with numerous branches and produce knotty, low-value lumber. Safe removal of urban elms might require destroying sawlogs as many diseased trees are taken down in sections because they are so close to buildings, overhead telephone wires, etc. Some sawmill operators are also hesitant about buying urban elms because undetected metal embedded in the trees can damage their equipment. (8)

Recovery of program costs through utilization of diseased trees is rarely compatible with good disease management practices as elm logs with the bark intact are often stockpiled for a long time in the municipality or at the sawmill before processing. To be biologically safe, hazardous elm wood must be disposed of or utilized promptly. Acceptable utilization methods, therefore, must be fast, render wood biologically safe, and help the municipality recover some of its tree removal costs. The following examples illustrate ways in which municipalities treat their diseased elm wood before utilization.

1. Elm wood can be fumigated under polyethylene cover with methyl bromide at or near tree removal sites. Local pesticide experts should be contacted for information. However, municipalities with a large number of diseased trees might find this method of utilization impractical. (3)

   Elm wood can also be covered with just the clear polyethylene plastic to prevent the invasion and spread of emerging bark beetles. However, this treatment does not kill mature elm bark beetles or larvae. To be biologically safe, any wood with its bark still intact after the plastic is removed must be burned in the winter, debarked, or re-covered with the plastic during periods of bark beetle activity. This method is inexpensive, relatively easy to apply, and involves no chemical treatment. (14)

2. Elm wood can be mechanically debarked or chipped to render it safe for a variety of purposes. For example, a portable log debarker can be transported easily between utilization sites. Crews cut the debarked logs into liftable pieces that can then be split into firewood lengths by a portable wood splitter. With this method, a large number of logs can be efficiently processed and made into biologically safe firewood. However, this debark-

ing method involves high-priced equipment and is only cost-effective if several communities combine their resources to cover all expenses, or if a municipality has many elms to process. (8,18)

Debarking produces biologically safe wood.

ADDITIONAL MANAGEMENT PRACTICES

The fundamental components of an effective Dutch elm disease management program include setting program boundaries; finding, marking, and removing diseased trees and other hazardous wood; and promptly disposing of or utilizing all biologically unsafe elm material. In addition, other management methods can be used to improve the biological and economic effectiveness of the overall program. The priorities given these additional methods vary according to geographical location and the amount of dollars, personnel, and equipment available to the program.

Dead Wood and Maintenance Pruning

Branches dead or dying from any cause should be pruned from otherwise healthy elm trees to eliminate a source of beetle broodwood material. It is best to prune during the fall and winter when beetles are inactive as there is the risk of attracting beetles to pruning wounds during the spring and summer. When storms or other events causing tree damage make spring and summer pruning unavoidable, that risk is minor compared with the benefits gained from removing potential beetle breeding sites. Many communities routinely prune trees to obtain a desired structure and appearance. To avoid attracting bark beetles to pruning wounds, healthy elm limbs should not be pruned during spring and summer. (18)

Therapeutic Pruning

Therapeutic pruning is the removal of tree branches showing early symptoms of Dutch elm disease. For best results, it should be attempted only when five percent or less of the tree crown is visibly infected. Early detection of wilting branches and prompt response are the most important steps in therapeutic pruning. The infection must be removed before it reaches the trunk and spreads through the entire tree (13). Therapeutic pruning is most successful when at least ten feet of healthy wood is cut off below the stained portion of the branch (4,18). However, the probability of completely removing the infection is increased with every additional foot taken beyond that ten feet of unstained wood. Therapeutically pruned trees must be examined throughout the season for recurring Dutch elm disease symptoms. Many arborists recommend that a tree wound dressing be used on pruning cuts made during months of beetle activity, although others question its effectiveness. Some advantages and limitations of therapeutic pruning are listed below.

Advantages:

1. Many diseased trees might be saved.
2. No special equipment or preparation is required.
3. The cost is less than tree and stump removal.
4. It is compatible with other management practices such as systemic fungicide injection and disruption of grafted roots (12).

Limitations:

1. It is only effective if the disease infection is caused by beetle inoculation.
2. Treatment of a tree with more than five percent of its crown visibly infected is rarely successful.

3. Because trees should be treated as soon as possible after disease detection — preferably the same day — flexibility in management operations might be reduced.

4. The symmetry or beauty of the tree is often adversely affected.

5. Bark beetles might be attracted to trees pruned during periods of beetle activity.

6. Therapeutic pruning does not replace fundamental disease management programs.

Prevention of Root to Root Spread of Dutch Elm Disease

Dutch elm disease can spread through the root systems of adjacent elms; the fungus can move from a diseased tree into a healthy one through grafted roots. Prevention of root transmission should be considered when a healthy tree is within 40 feet of a diseased one that is to be removed. It is most beneficial in areas where root graft transmission is responsible for more than 50 percent of new infections (18).

Ceratocystis ulmi can be spread through grafted roots.

It is recommended that connected roots be severed mechanically, using vibratory plows, mechanical trenchers, back-hoes, and even hand spades, wherever above- and below-ground conditions permit. Grafted roots should be severed 18-36 inches (refer to the recommendations made by local specialists) below the ground. Mechanical severing should be done before the tree is removed.

Vibratory plows can be rented from local utility companies, which use them to place underground wires and cables. To minimize turf damage the plow blade should be narrow. The plow and its operator should be hired on an hourly or per foot basis and the cost of packing down the plowed seam should be included in the contract.

Vibratory plows are used in some instances to sever grafted roots.

Vibratory plows cause little damage to the landscape.

Utility companies will also rent mechanical (soil) trenchers, which are less expensive and more readily available than vibratory plows. A unit and an operator can be rented by the hour or by the foot. Trenchers can also be leased by the week or month and operated by a city employee. Trenches should be as narrow as possible so that less backfilling is needed. After severing the roots, the trench should be filled immediately, with additional backfilling done later as the soil settles.

Trenchers require hand labor for cleanup.

Soil fumigants kill turf along the treatment line.

Each situation must be evaluated individually before determining whether a mechanical or chemical treatment will be most effective in disrupting grafted roots. The following steps should be considered when selecting a treatment method:

1. Check above-ground conditions. Vibratory plows and mechanical trenchers cannot be used on paved surfaces such as streets, sidewalks, and driveways. Chemicals should not be used within 20 feet of healthy trees and shrubs (4).
2. Determine below-ground conditions. Vibratory plows and soil trenchers can sever buried telephone cables and electric, water, and gas lines. It is also difficult to use them in rocky areas.

Where grafted roots cannot be severed mechanically, chemical treatment with a soil fumigant is recommended (19). To do this, a chemical is poured into a series of holes placed between the diseased tree and its healthy neighbor. A list of usable chemicals can be obtained from county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations. After fumigation, the diseased tree cannot be removed until the chemical has penetrated the soil and destroyed the grafted roots. If the infected tree is removed before the chemical has a chance to work, healthy elms that are root grafted to the infected one will draw sap containing the fungus out of the remaining stump and root system before the root grafts are killed, thus becoming infected themselves. Whenever a chemical is used, the label directions for application, storage, and safety precautions must be carefully followed. Although fumigation is slower than trenching, might not destroy roots larger than $1\,1/2$ inches in diameter, and can damage landscape material, it is often the only practical way to destroy the grafted roots.

When the decision is made to remove an elm, a girdling cut into the sapwood at the base of the tree will stop the downward movement of the fungus. Where there is a possibility of transmission of the fungus from a diseased elm to adjacent healthy ones through root grafts, immediately girdling the diseased elm to limit the spread of the fungus should be considered (2,6).

Insecticide Spraying

The fungus that causes Dutch elm disease, *Ceratocystis ulmi* (Buisman) C. Moreau, can be carried to healthy trees by one or two species of elm bark beetles. Introduction of the fungus occurs during feeding or breeding activities. Inoculation of healthy trees can be reduced or prevented by application of insecticides.

In areas where the native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff), is an important vector of Dutch elm disease, an insecticide can be used to reduce overwintering population levels (18). Native elm bark beetles overwinter mainly as adults at the bases of healthy elms, thus escaping late-season removal of dead or dying elm wood. Insecticide sprayed on the lower six feet of healthy elms can kill beetles as they make their overwintering tunnels or as they emerge in the spring to begin feeding on healthy elms. Root flares should also be sprayed, since beetles concentrate in these areas. Although the insecticide can be applied in the fall or in the spring, early fall treatments are best because the beetles are killed before they transmit Dutch elm disease as they make overwintering tunnels. Spraying to reduce native elm bark beetle populations should be done community-wide to be effective.

Trunk treatments with insecticides can provide satisfactory control of the native elm bark beetle when properly applied.

Insecticides can also be used to reduce twig-crotch feeding by the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham) (25). Dormant (pre-leaf emergence) applications of certain registered insecticides that act as contact and stomach poisons can kill the beetles or prevent their feeding. Elm trees must be sprayed with these chemicals before the beetles become active in the spring. Insecticides should be sprayed on days with little or no wind when temperatures are above freezing. The insecticide's effectiveness can be reduced if it rains immediately after application. Spray applications made anytime during the dormant period (fall, winter, or spring) will remain effective during periods of bark beetle activity. All bark surfaces must be completely covered with these chemicals to prevent beetle feeding. **THOROUGHNESS IS IMPORTANT.** Special care should be taken to cover the upper and outer parts of the tree crown; this is difficult in large trees. (19) These chemicals work slowly as contact and stomach poisons, however, and the beetles often have enough time to penetrate the bark and transmit the Dutch elm disease fungus before dying. Other disadvantages of spraying are the expense and the possibility of over-spray and drift.

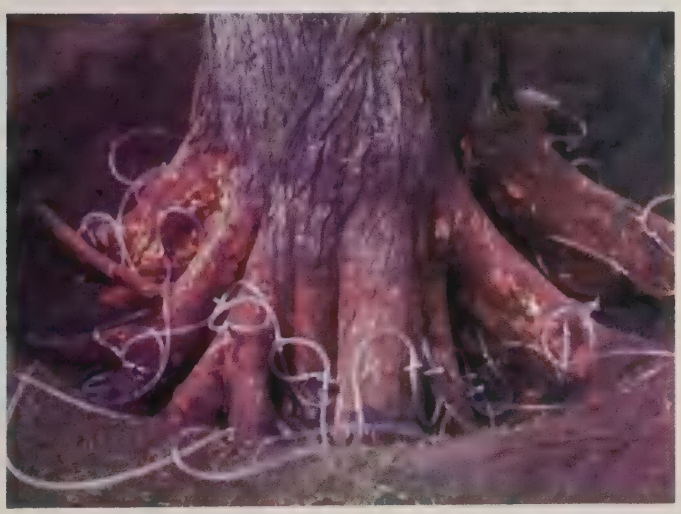
The smaller European elm bark beetle feeds in the elm twig crotches.

Insecticides used alone do not stop the spread of Dutch elm disease. They must be used in addition to prompt removal and disposal of diseased and hazardous elm wood. Whenever a chemical is used, the label directions for application, storage, and safety precautions must be carefully followed.

A list of the insecticides that can be used against the native and smaller European elm bark beetles can be obtained from county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations.

Systemic Fungicide Injection

Systemic fungicides can be used as a preventive treatment to give highly valued elms added protection against the disease fungus (11). Injection can be costly. It is most often used on those trees that are aesthetically or historically valuable to the municipality or to the individual homeowner. Since this management practice is recommended only for a small percentage of elms, it has little impact on reducing disease incidence. Systemic fungicide injection is effective only when broodwood material and diseased trees are removed and properly disposed of or utilized. **SYSTEMIC FUNGICIDE INJECTION IS AN AID TO THE OVERALL MANAGEMENT PROGRAM, BUT ITS PERFORMANCE IS NOT GUARANTEED.** The fungicide is injected through a series of holes drilled in the root flares of the tree, causing physical damage that might make the tree vulnerable to other disease problems (22). For best results, injection should be done soon after leaves reach full size. Injecting before the tree is fully leafed-out might reduce the treatment's effectiveness because the tree cannot adequately absorb and transport the fungicide to the uppermost branches. The decision to inject a tree with a systemic fungicide must be made carefully; the expense, the possible lack of effectiveness, and the result of physical damage to the tree must all be considered (5).



Excavation of the flare roots is preferred for injection.

A municipality or an individual homeowner might want to inject an already diseased tree. This is a therapeutic treatment. Greatest success is obtained when trees with crown infections of five percent or less are treated. The effectiveness of a therapeutic injection can be increased if the diseased portion of the tree is pruned out following the fungicide treatment. Injection is not likely to be effective when used on trees with massive wilt or trees infected through root grafts. In these situations, the disease fungus is usually well established in the main trunk, restricting movement of the fungicide.

Advantages:

1. When used as a preventive treatment, the fungicide can give the tree added protection against the disease fungus.
2. Fungus reproduction is inhibited, reducing or stabilizing the amount of inoculum present within the tree. Symptom development can be temporarily arrested.
3. The fungicide limits downward movement of the causal fungus and reduces disease spread into larger branches. The tree might be able to completely wall off the fungus following injection.

Limitations:

1. Correct application is difficult. It is important to follow the manufacturer's instructions on how to mix the chemical selected.
2. The pathogen is only temporarily inactivated and might continue to develop later. Additional injections might be required.
3. Incomplete protection might result because it is difficult to get uniform distribution of the fungicide within a tree.
4. Recommended amounts of the fungicide might be toxic (poisonous) to the tree, resulting in leaf discoloration, premature defoliation, abnormal growth, and/or death of branch terminals.
5. Injection wounds damage the tree physically and increase the tree's susceptibility to other diseases.

Individuals can get information on what systemic fungicides to use and how to apply them from county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations.

Elimination of Wild Elm

Some municipalities have forested areas with a large number of wild elm. Pockets of wild elm within a community's designated disease management zone are usually a source of new infections and are a threat to the overall management program. To stop the spread of Dutch elm disease from these areas to the urban elm population, all the wild elm can be removed in one operation. This management effort eliminates the hazardous wild elm and saves time and dollars. It will only be necessary to take equipment into a difficult area once and tree inspectors will not have to make return trips to mark newly infected elms. When an area is clear-cut of wild elm, it is not denuded; other tree species are not removed. Soil erosion does not become a problem as there is usually sufficient undergrowth remaining. Trees that are cut must be removed and burned, buried, or utilized in some way.

The wild elm hazard can also be eliminated chemically. Herbicides that cause rapid wood desiccation can be applied to cuts around the trunk or injected into the root flares of the trees. This treatment will kill beetle eggs and larvae. Applications should be made when leaves are fully emerged to allow translocation of the chemical throughout the entire tree (20). Information about which herbicides to use and how to apply them can be obtained from county extension agents, local colleges or state universities, and state or federal forestry/agricultural organizations.

PROGRAM COSTS

Many agencies and universities have documented the status of Dutch elm disease within their jurisdiction and have described the disease conditions unique to their area (4,9,18,19,20,23,25,26,27). Much of this literature describes the biology of the casual fungus and the life cycle of the two disease-transmitting beetles and often recommends how to develop and maintain an effective disease management program. Although the cost of these recommended programs might be mentioned, a detailed list of expenses is rarely given. Thus, it is difficult for a community thinking of starting a program to make budget estimates.

To give communities a better idea of the expenses involved in Dutch elm disease management, the following four hypothetical programs are presented. Although they are not actual programs, they are based on results of case studies from the five-state National Dutch Elm Disease Demonstration Program (27). The goal of that program was to achieve or maintain annual disease losses of 5 percent or less. Information from previous economic analyses of Dutch elm disease management programs was also used in developing these case studies (7,21). The states participating in the demonstration program — California, Colorado, Georgia, Minnesota, and Wisconsin — reflected the national diversity in Dutch elm disease incidence. For example, Georgia had neither the large elm population nor the devastating disease losses of Minnesota and Wisconsin. Despite the differences in geography and extent of disease activity, these states had similar problems. Each state had to integrate Dutch elm disease management practices into existing community tree removal programs, evaluate them as to usefulness and cost-effectiveness, revise them as needed, and assign them a priority. Each of the four examples illustrates the organization and cost of a program tailored to the different circumstances of these states. In all four, it is assumed that the city pays for tree removal on private as well as public property. Figures are based on 1982 dollars.

Sample Program 1

Highlights: **SMALL, COMPACT TOWN; FEW ELM TREES.**

Situation: This town of 4,500 residents was 4 miles square and compact. Elms constituted 20 percent (4,000 trees) of the total tree population of 20,000. Without a management program, the annual Dutch elm disease incidence was 2 per-

cent. Wild elms were not a threat since the city was surrounded by farm land. The smaller European elm bark beetle was the insect vector.

Program Summary: Since this was a small town with a low disease incidence, a qualified tree inspector was hired for the active season only. The public works department maintained the program during the rest of the year. Town crews removed all the diseased elms and the average tree removal cost was high. Private contractors did not want to bid on the job because of the small number of trees to be removed, so removal costs were not reduced by competitive bidding. Because the disease incidence was low, the tree inspector was able to spend some time on therapeutic pruning and disruption of grafted roots.

Result: At the end of 4 years with a management program, the annual disease incidence remained at 2 percent. This was an achievement because only through an intensive effort was the disease incidence kept at the same, manageable level for four years and not allowed to go any higher.

Annual Budget

Personnel	
— one full-time tree inspector wages ($5.50 per hour, 40 hours per week, for 20 weeks)	$ 4,400.00
fringe benefits	572.00
	$ 4,972.00
Equipment Rental	
— vehicle for tree inspector $78.00 per week, for 20 weeks	$ 1,560.00
— one aerial bucket truck for tree sampling $35.00 per hour, for 10 hours	350.00
	$ 1,910.00
Disease Management Practices	
— removal of trees and stumps $150.00 per tree, for 80 trees	$ 12,000.00
— therapeutic pruning $50.00 per tree, for 20 trees	1,000.00
— trimming dead wood from elm trees	5,000.00
— installing root graft barriers $20.00 per barrier, for 30 barriers	600.00
— use of systemic fungicides $50.00 per application, for 10 trees	500.00
	$ 19,100.00
Miscellaneous Small Equipment and Supplies	**$ 200.00**
Program Total	**$ 26,182.00**

Sample Program 2

Highlights: **SMALL CITY; WILD ELMS PRESENT.**

Situation: This city of 8,000 residents was 5 miles square and divided by a river. Elms constituted 12 percent (12,000 trees) of the total tree population of 100,000. Without a management program, the annual Dutch elm disease incidence was 5 percent. Wild elms grew in abundance along the river. The smaller European elm bark beetle was the insect vector.

Program Summary: Wild elm populations made disease surveys in this city difficult to perform, so two tree inspectors were hired for the active season. The public works department administered the program for the rest of the year. A private contractor removed all the diseased elms. There was competitive bidding for the contract because there were so many trees to be removed and this kept the average tree removal cost relatively low. Although some therapeutic pruning was done, more time was spent on disrupting grafted roots because many disease infections had spread by root graft transmission.

Result: At the end of 4 years with a management program, the annual disease incidence was reduced to 4 percent. Without a program, the disease incidence would probably have reached an unmanageable level within the four years. By keeping a close watch on the disease situation and maintaining a good program, however, this city was able to lower the disease incidence by 1 percent.

Annual Budget

Personnel	
— one full-time tree inspector wages ($6.50 per hour, 40 hours per week, for 24 weeks)	$ 6,240.00
— one assistant, full-time tree inspector wages ($5.90 per hour, 40 hours per week, for 14 weeks)	3,304.00
— fringe benefits for above positions	1,245.00
	$ 10,789.00
Equipment Rental	
— mileage for tree inspectors' vehicle $.20 per mile, 150 miles per week, for 24 weeks	$ 720.00
— one aerial bucket truck for tree sampling $35.00 per hour, for 20 hours	700.00
	$ 1,420.00

Disease Management Practices	
— removal of trees and stumps	
$70.00 per tree, for 600 trees	$ 42,000.00
— therapeutic pruning	
$50.00 per tree, for 10 trees	500.00
— trimming dead wood from elm trees	6,000.00
— installing root graft barriers	
$20.00 per barrier, for 50 barriers	1,000.00
— use of systemic fungicides	
$50.00 per application, for 20 trees	1,000.00
	$ 50,500.00
Miscellaneous Small Equipment and Supplies	**$ 200.00**
Program Total	**$ 62,909.00**

Sample Program 3

Highlights: **MEDIUM-SIZED CITY; LARGE AREA; HIGH DISEASE INCIDENCE.**

Situation: This city of 16,000 residents was 8 miles square. Elms constituted approximately 13 percent (14,000 trees) of the total tree population of 105,000. Without a management program, the annual Dutch elm disease incidence was 10 percent. The city was isolated from wild elm populations but was in an area of the nation that had suffered great losses due to Dutch elm disease. The smaller European elm bark beetle and the native elm bark beetle were the insect vectors.

Program Summary: This city had such a problem with Dutch elm disease that a permanent forester was hired; an additional tree inspector was hired for the active season. A laborer disrupted grafted roots and injected trees with a fungicide. This allowed the forester and tree inspector more time to complete disease surveys and supervise tree removal. City crews removed diseased trees on public property and a private contractor removed diseased trees on residential property. Time was spent on disrupting grafted roots because many infections had spread this way. An insecticide was also used to control native elm bark beetle populations.

Result: At the end of 4 years with a management program, the annual disease incidence was reduced from the almost unmanageable level of 10 percent to 5 percent.

Annual Budget

Personnel	
— one full-time forester	$ 17,000.00
— one seasonal, full-time tree inspector wages ($5.90 per hour, 40 hours per week, for 14 weeks)	3,304.00
— fringe benefits for above positions	2,640.00
— one seasonal laborer (to assist with root graft barrier placement, tree injection, etc.) wages ($4.75 per hour, 300 hours per season)	1,425.00
	$ 24,369.00
Equipment Rental	
— vehicle for city forester $200.00 per month, for 12 months	$ 2,400.00
— vehicle for seasonal tree inspector $200.00 per month, for 3 1/2 months	700.00
— one aerial bucket truck for tree sampling $35.00 per hour, for 50 hours	1,750.00
	$ 4,850.00
Disease Management Practices	
— removal of trees and stumps $80.00 per tree, for 1,400 trees	$ 112,000.00
— therapeutic pruning $50.00 per tree, for 20 trees	1,000.00
— trimming dead wood from elm trees	6,000.00
— installing root graft barriers $20.00 per barrier, for 50 barriers	1,000.00
— use of systemic fungicides $50.00 per application, for 30 trees	1,500.00
— insecticide to control native elm bark beetles	1,000.00
	$ 122,500.00
Miscellaneous Small Equipment and Supplies	**$ 200.00**
Program Total	**$ 151,919.00**

Sample Program 4

Highlights: **SMALL CITY; LARGE AREA; FEW ELMS.**

Situation: This city of 10,300 residents covered 9 1/2 square miles. The 2,054 elms constituted less than 1 percent of the total tree population of 650,000. Without a management program, the annual Dutch elm disease incidence was 4.2 percent. Most of the elms were in key locations downtown and around homes; 10 percent were on public property. The smaller European elm bark beetle was the insect vector.

Program Summary: Because there had been no prior program, management costs were high for the first two years when disease practices were

being initiated. During each spring and summer, a part-time worker was hired for surveying and mapping. All tree removal and pruning work was done by private contractors.

Result: At the end of 4 years with a management program, less than 1 percent of the original elm population was being removed annually.

Annual Budgets

YEAR ONE:	
87 trees removed at $145.00 per tree	$ 12,615.00
25 trees therapeutically pruned at $55.00 per tree	1,375.00
1 part-time worker	2,000.00
Program Total	**$ 15,990.00**
YEAR TWO:	
90 trees removed at $145.00 per tree	$ 13,050.00
51 trees therapeutically pruned at $55.00 per tree	2,805.00
1 part-time worker	2,000.00
Program Total	**$ 17,855.00**
YEAR THREE:	
30 trees removed at $145.00 per tree	$ 4,350.00
6 trees therapeutically pruned at $55.00 per tree	330.00
1 part-time worker	2,000.00
Program Total	**$ 6,680.00**
YEAR FOUR:	
11 trees removed at $145.00 per tree	$ 1,595.00
5 trees therapeutically pruned at $55.00 per tree	275.00
1 part-time worker	2,000.00
Program Total	**$ 3,870.00**

PROGRAM RETURNS

The impact of Dutch elm disease is not often noticed by the general public until the number of infected trees becomes unmanageable and stump-lined boulevards are suddenly visible. Disease experts can project how much the cost of an elm management program will increase for every year its start is delayed (7,23). Such projections were made for the City of Little Falls, Minnesota.

Little Falls — Elm Loss Trend

The City's total elm population in 1977 was 12,165 trees. With a management program, 9,877 elm trees, 81 percent of the City's original 1977 population, were still standing at the end of 1982. Projections show that if there had been no program, only 44 percent of the original 1977 elm population, 5,341 trees, would have remained.

Table 1. Real elm losses in Little Falls, 1978-1982, with a program.

Year	Elm Losses	Remaining Elms	Percent of Original Elm Population Remaining	Disease Incidence (Percent)
1978	677	11,488	94	5.6
1979	516	10,972	90	4.5
1980	365	10,607	87	3.3
1981	487	10,120	83	4.6
1982	243	9,877	81	2.4
	2,288			

Table 2. Projected elm losses in Little Falls, 1978-1982, without a program.

Year	Elm Losses	Remaining Elms	Percent of Original Elm Population Remaining	Disease Incidence (Percent)
1978	677	11,488	94	5.6
1979	965	10,523	87	8.4
1980	1,326	9,197	76	12.6
1981	1,738	7,459	61	18.9
1982	2,118	5,341	44	28.4
	6,824			

Little Falls — Program Costs

Total elm population in 1978 was 11,488 trees.
The City paid for tree removal costs
incurred on private as well as public property.

Year	Average Tree Removal Cost	Real Costs With A Program		Projected Costs Without A Program	
1979	$38.00	Removal of 516 trees	$19,608.00	Removal of 965 trees	$ 36,670.00
		Remaining program costs	29,960.00	Remaining program costs	-0-
		Total	**$49,568.00**	**Total**	**$ 36,670.00**
1980	$58.00	Removal of 365 trees	$21,170.00	Removal of 1,326 trees	$ 76,908.00
		Remaining program costs	32,360.00	Remaining program costs	-0-
		Total	**$53,530.00**	**Total**	**$ 76,908.00**
1981	$59.00	Removal of 487 trees	$28,733.00	Removal of 1,738 trees	$102,542.00
		Remaining program costs	25,760.00	Remaining program costs	-0-
		Total	**$54,493.00**	**Total**	**$102,542.00**
1982	$108.00	Removal of 243 trees	$26,244.00	Removal of 2,118 trees	$228,744.00
		Remaining program costs	-0-	Remaining program costs	-0-
		Total	**$26,244.00**	**Total**	**$228,744.00**
		1979-1982 Total	**$183,835.00**	**1979 — 1982 Total**	**$444,864.00**

From 1979 to 1982, the City of Little Falls spent $183,835.00 on Dutch elm disease management, but had 9,877 elm trees, 86 percent of its original 1978 population, left at the end of that time. Without a program to reduce disease losses, Little Falls would have spent $444,864.00 removing infected trees, and only 5,341 elms, 46 percent of the original 1978 population, would remain. With a program, a city can spread losses and management costs over a long time period, enabling it to handle its disease problem economically. With Dutch elm disease, a city must not choose to do nothing. Diseased elms must be removed because they become hazards. In their weakened condition, infected trees can fall on cars, buildings, power lines, etc. Consequently, they must be removed unless the city or the homeowner is willing to be held liable for any damage that might occur. Also, a city without a program can lose the majority of its elm population in just a few years.

The economic analysis presented here illustrates the monetary advantages of having a community Dutch elm disease management program. However, there are other benefits to be gained by having one. Elms that are historically valuable and aesthetically pleasing to the community might be saved or at least not all lost within one or two years. With a management program, the community's environment is not changed overnight due to a massive loss of urban elms. Energy conservation is also practiced when a management program is maintained. Those elms that keep houses cool in the summer with their shade and reduce the effects of wind and snow blowing against the house in winter, have a better chance of surviving additional years. So, there are other incentives besides financial ones that should encourage a community to have a Dutch elm disease management program.

CONCLUSION

A community's responsibility does not end with the decision to develop a Dutch elm disease management program. Any tree care program must be reassessed constantly to incorporate changing priorities. For example, in the first year or two of a Dutch elm disease program, the primary concern is to remove dead or dying trees. In later years, program emphasis shifts to detecting trees in the initial stages of the disease and using other management practices such as therapeutic pruning or disrupting grafted roots. A progressive tree care program continually changes. Elm losses can be maintained at manageable levels by using the guidelines in this publication. Additional information can be obtained from various studies and bibliographies on Dutch elm disease (15,16,23).

Dutch elm disease is not the only hazard faced by urban trees. Because of the massive losses it has caused, however, Dutch elm disease has often been the catalyst that many communities have needed to begin comprehensive urban forestry programs. The intensive inspection surveys used in Dutch elm disease management can easily be adapted to encompass a search for all types of trees that are diseased or in need of care. The practices discussed in this publication can be used to develop management programs that can be applied not only to Dutch elm disease but to other tree diseases and all aspects of urban forestry as well. With the many empty spaces now in the landscape due to the loss of the elms, the planting of new trees has been encouraged. Communities now recognize the importance of planting trees on a continual basis so the urban forest will consist of trees varying in age. Most of all, Dutch elm disease has demonstrated nationwide the danger of planting an entire forest to one tree species.

YOU CHOOSE. . . .

Elm trees produce shade and other valuable urban assets.

Without the elm, many urban areas would be bare.

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APPENDIX: CONTRIBUTORS

The primary participants in the five-state Dutch Elm Disease Demonstration Program are listed below. From 1978 through 1981, these people developed, administered, and evaluated Dutch elm disease management practices. For some it was a full-time job; for others, it was just one of several responsibilities. Together these people formed the backbone of a successful disease management program.

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Chemical treatments are described in this publication for the purpose of providing information on Dutch elm disease. Persons using the treatments described herein assume full liability for their use in accordance with current label directions of the manufacturer. All safety precautions should be followed to prevent pollution or damage to humans, plants, and animals.